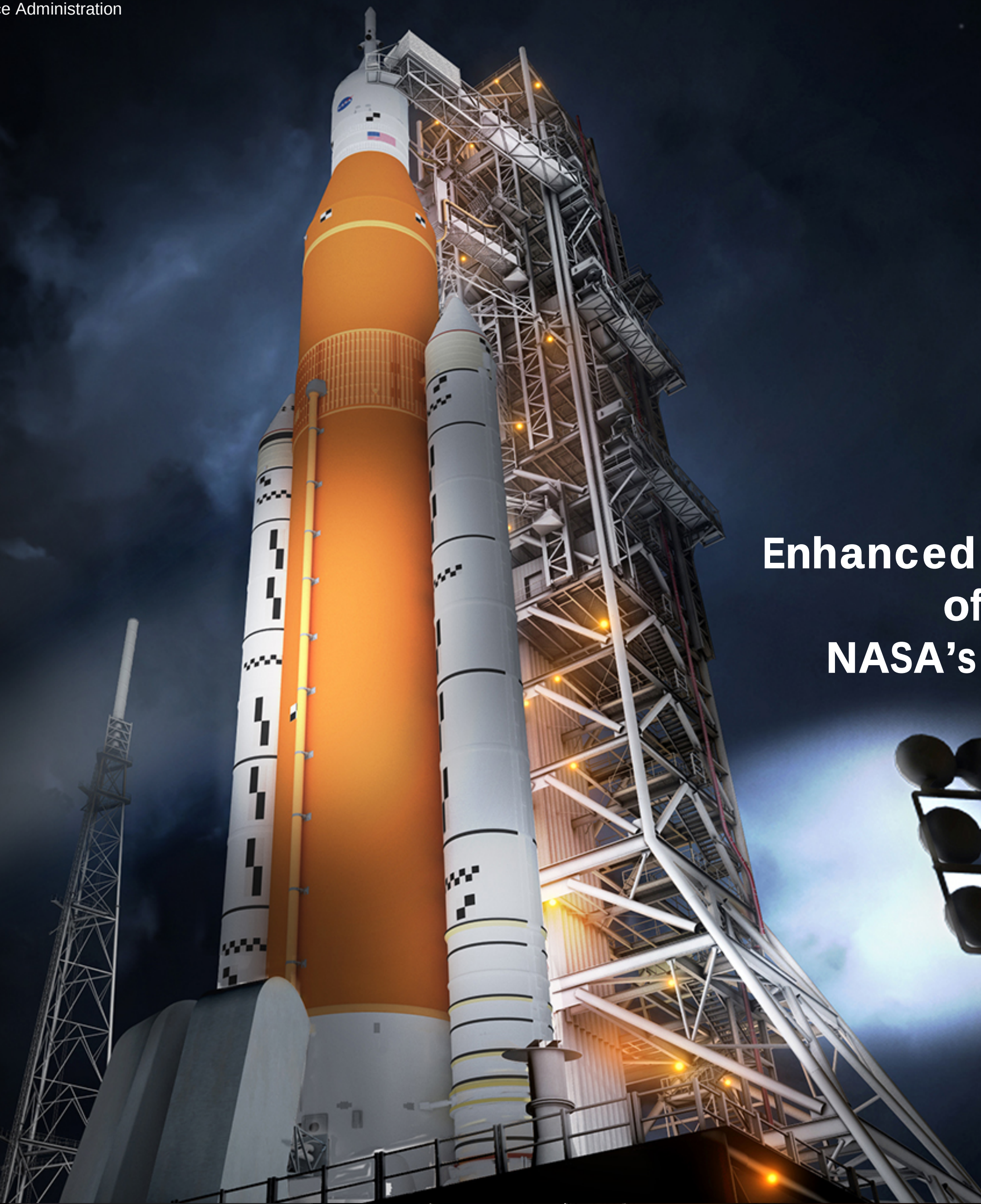
National Aeronautics and Space Administration



SPACE LAUNCH SYSTEM

Enhanced Feasibility Assessment of Payload Adapters for NASA's Space Launch System

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Terry Sanders
David Alan Smith

OBJECTIVE

- **Challenge**
  - Development of 8.4m diameter Space Launch System (SLS) requires new family of 8.4m Payload Adapters (PLA)
  - SLS PLAs need to accommodate unique requirements (relative to existing launch vehicles) including payload types, sizes, mass, and trajectories

- **Solution**
  - Iterative PLA design approach to optimize performance, reduce mass, increase potential model reusability

- **Approach**
  - Apply a Model Based System Engineering (MBSE) approach to managing data flow through PLA design-analyze-build process

AGENDA

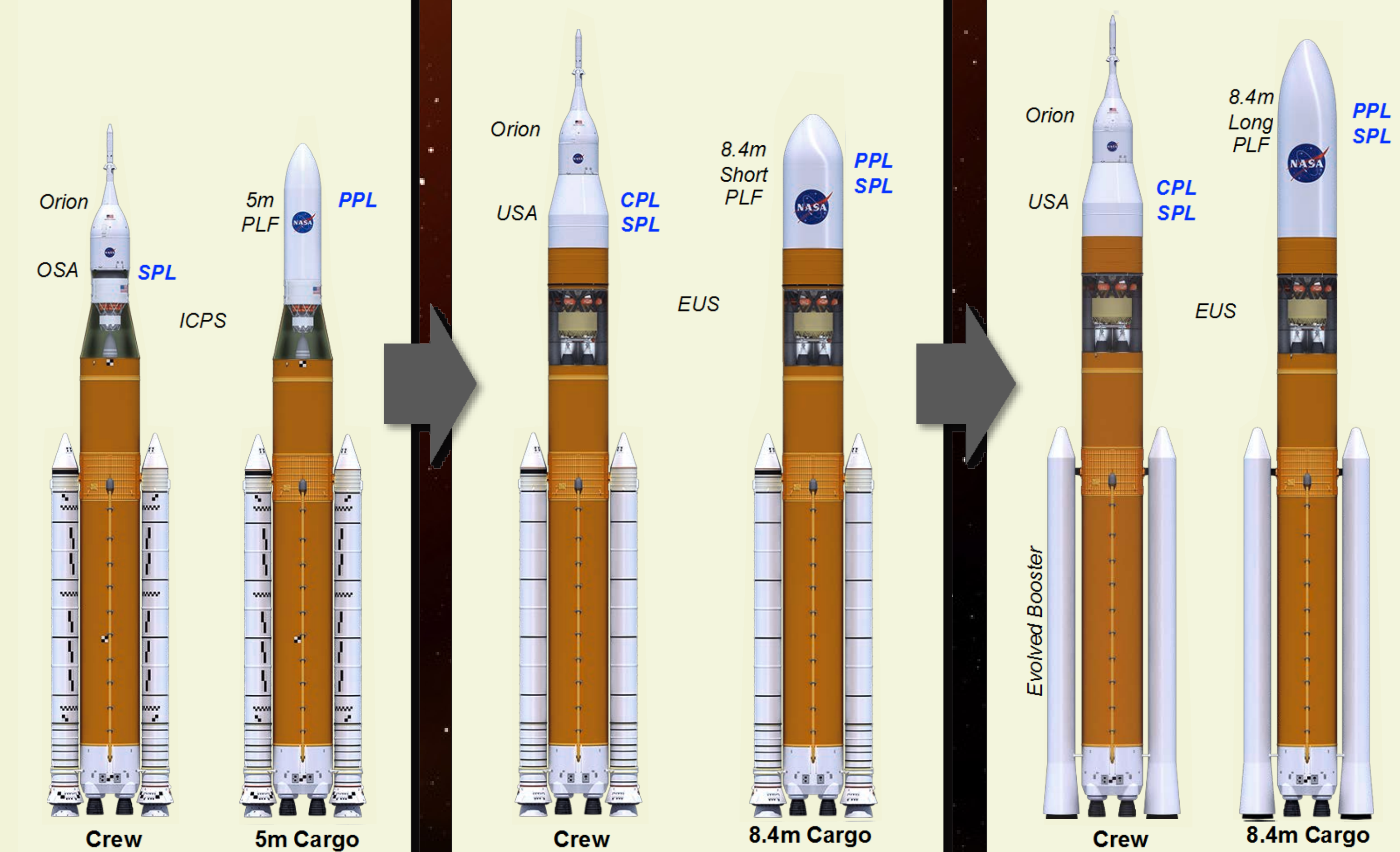
- **Part 1**
  - Understand the unique payload accommodation requirements of SLS PLA
  - Establishes trade study constraints
- **Part 2**
  - Discuss results of NASA Engineering and Safety Center (NESC) - sponsored PLA MBSE pathfinder
  - Conclusions
  - Future Work

SLS BLOCK CONFIGURATIONS

SLS Block 1
>26t to TLI
(No Earlier than 2020)

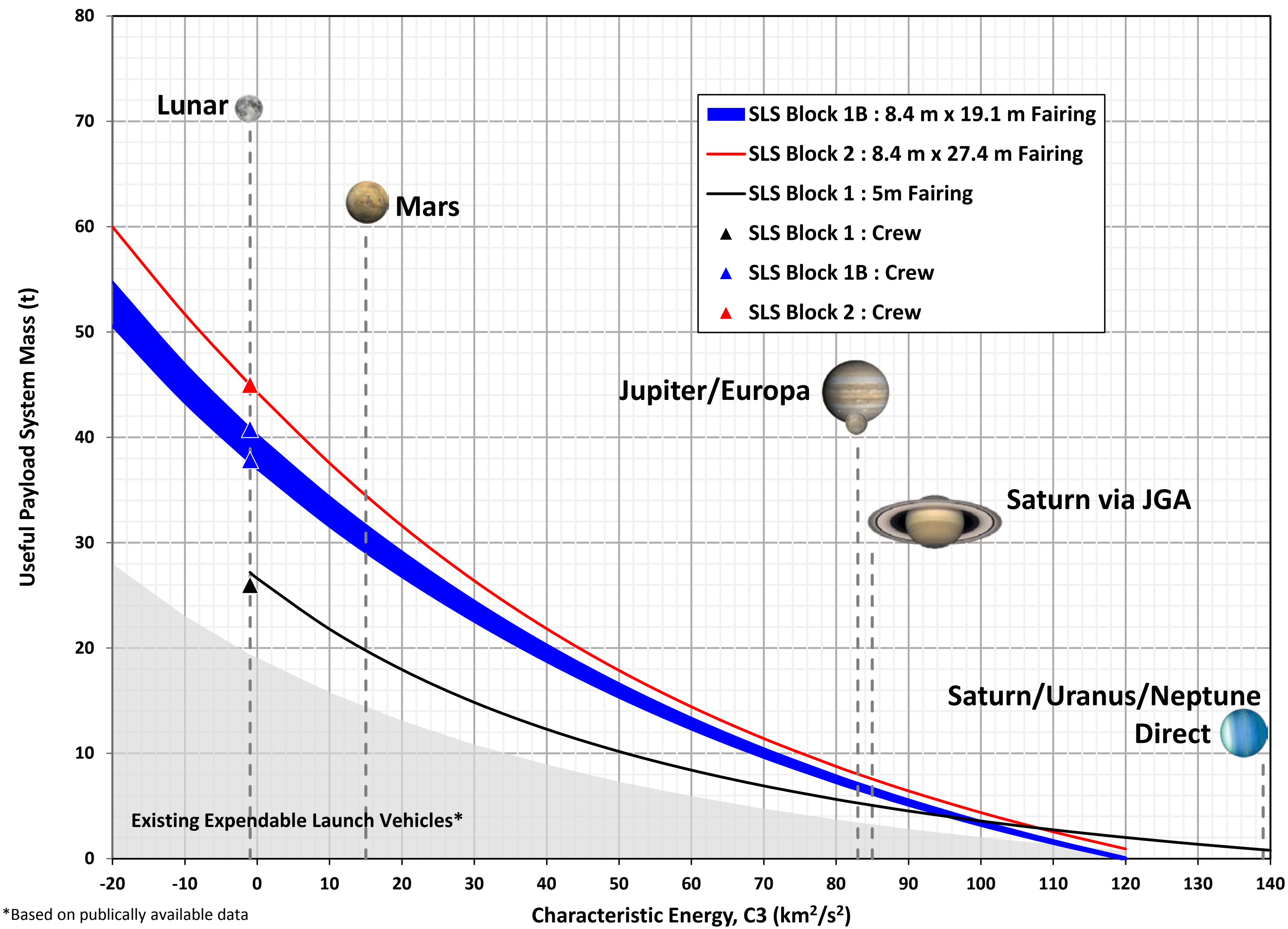
SLS Block 1B
34 - 40t to TLI
(No Earlier than 2024)

SLS Block 2
>45t to TLI
(No Earlier than 2029)



OSA - Orion Stage Adapter ICPS - Interim Cryogenic Propulsion Stage PLF - Payload Fairing EUS – Exploration Upper Stage USA – Universal Stage Adapter
PPL – Primary Payload CPL – Co-manifested Payload SPL – Secondary Payload

SLS PAYLOAD MISSION CAPTURE



*Based on publically available data

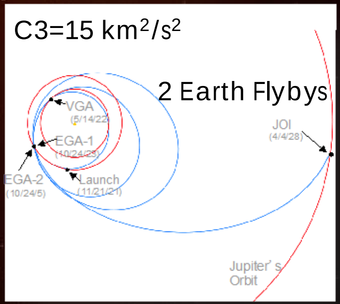
07-SEP-2018

Rev. 6

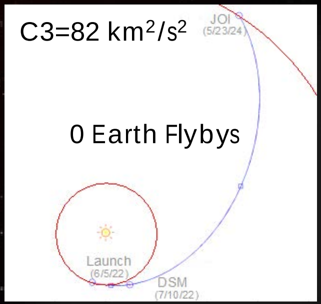
SLS TIME TO DESTINATION

- **Shorter Transit Times to Destination**
- **Europa Clipper**
  - Desired launch date of June 2022
  - Jovian system transit time reduced by 65% over existing launch vehicles
  - Reduced mission operations cost over time

Current LVs



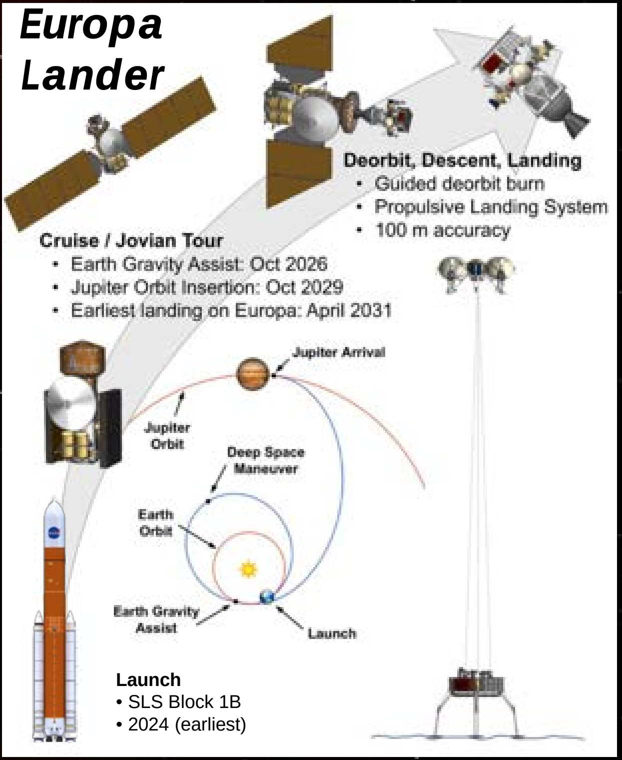
SLS



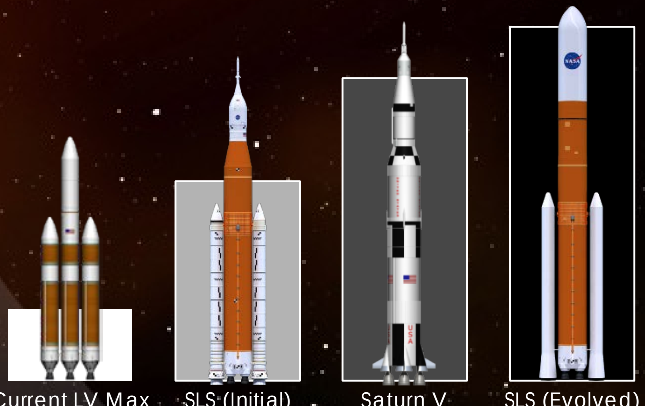
Earliest Launch	Cruise:	Jupiter Orbit Insertion	Jovian System Operations
*Period: 6/4/22 – 6/24/22 (SLS) *Period: 6/18/22 – 7/8/22 (Atlas)	2.5 Years (SLS) 7.4 Years (Atlas)	12/24/24 or 5/1/25 (SLS) 11/26/29 (Atlas)	Prime Europa Flyby Campaign: 36 months

SLS MASS TO DESTINATION

- **Up to 5 times greater mass to orbit capability than current launch systems**
  - Increases payload mass margins
  - Offers range of injection propulsion options
- **New Horizons**
  - SLS would have doubled delivered payload mass to Pluto
- **Europa Lander**
  - 16 mT delivery to outer planets (with margin)

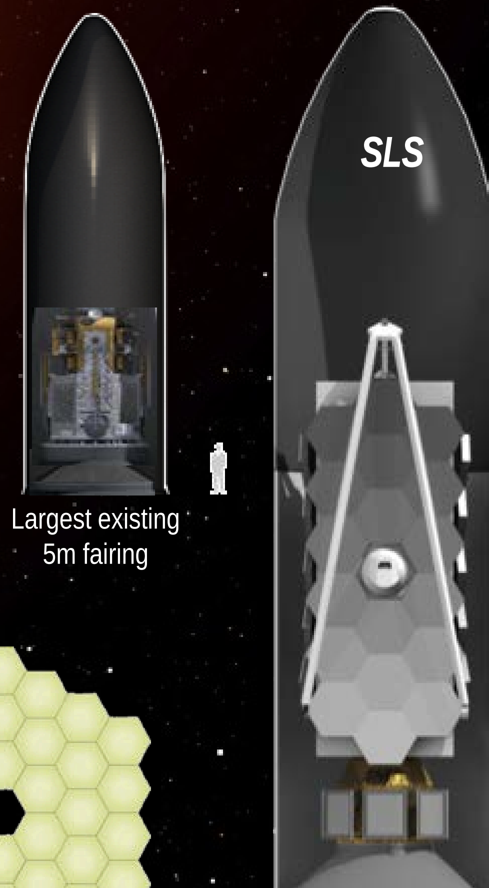


Payload Lift Comparison



SLS VOLUME TO DESTINATION

- **Up to 6 times greater volume available**
- **Multiple payload combinations**
  - Dual manifesting within fairing
  - Payload constellations
  - More powerful injection stages
- **Telescopes**
  - Larger payloads translate into simpler orbital operations (fewer deployments)



Largest existing 5m fairing

8m fairing with large aperture telescope

2.4 m Hubble (monolithic)

6.6 m James Webb (segmented)

8 m (monolithic)

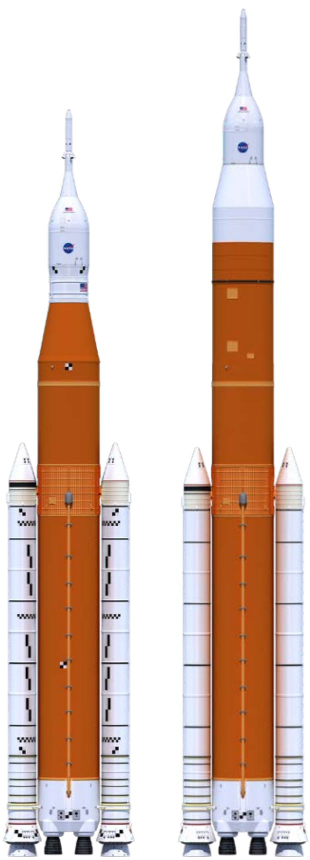
11 m (segmented)

12.5 m (segmented)

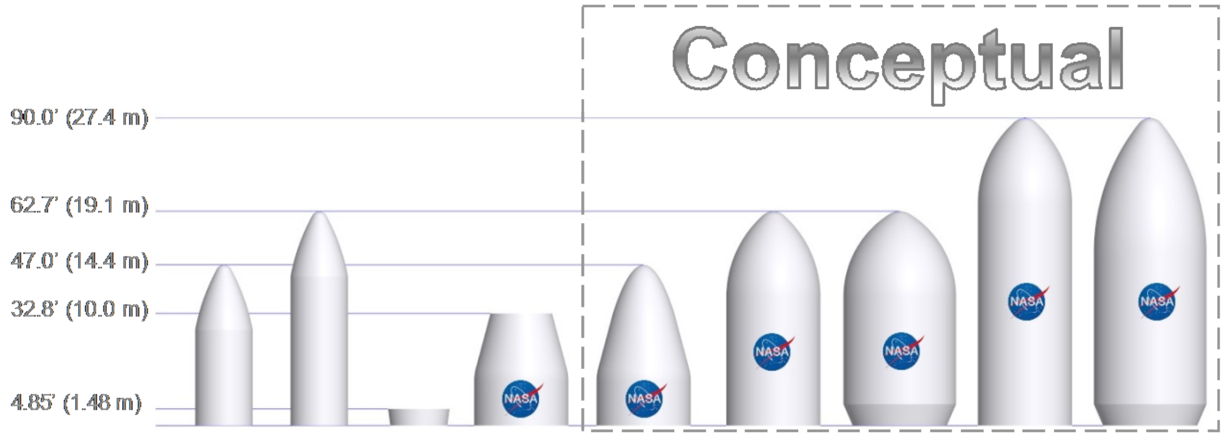
16 m (segmented)

Architectures Enabled by SLS

RANGE OF PAYLOAD ENCAPSULATION



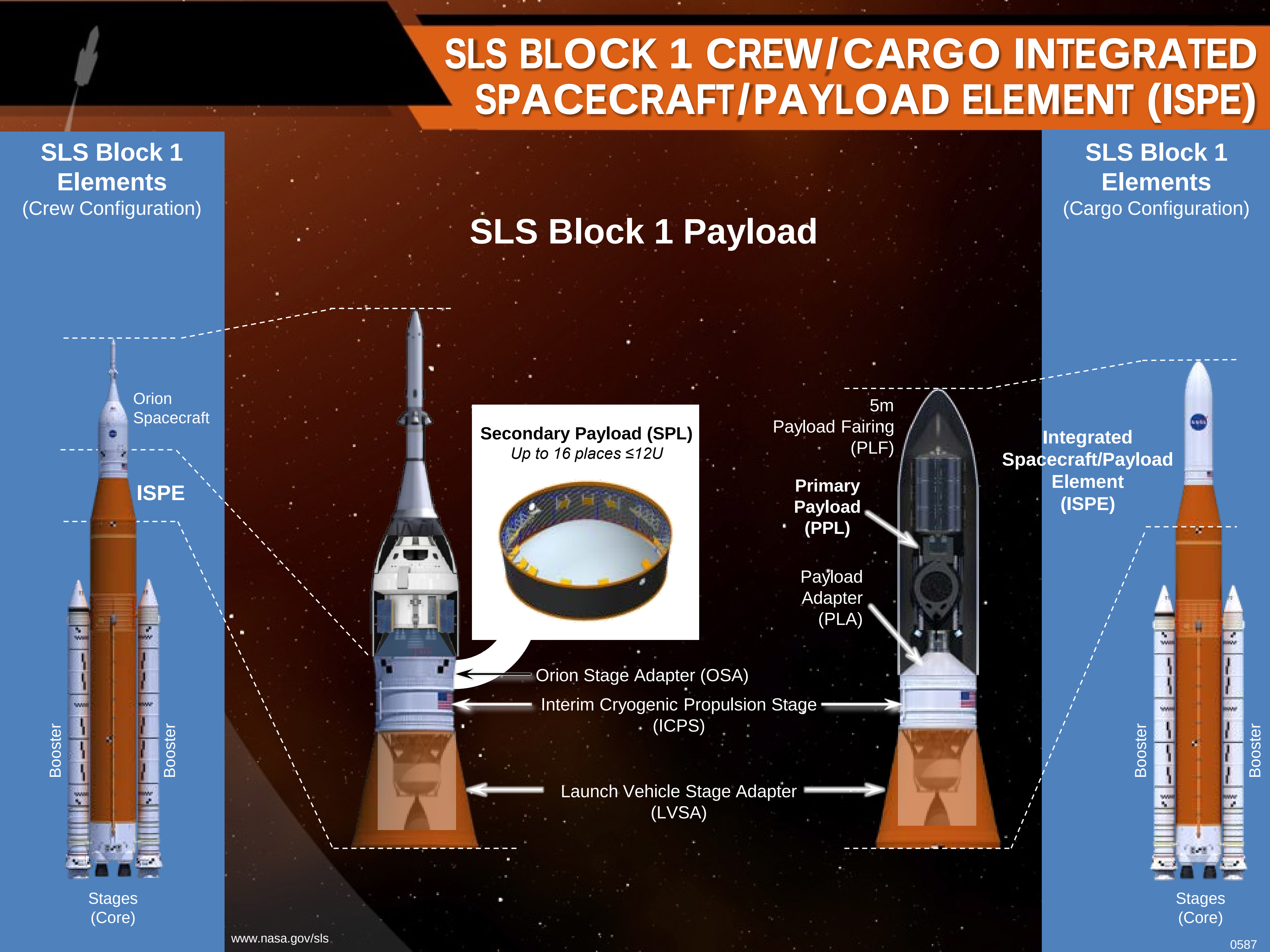
Block 1 Block 1B



Enclosure	5.1m PLF	5.1m PLF	OSA	8.4m USA	8.4m USA PLF	8.4m PLF, Short	10m PLF Short	8.4m PLF, Long	10m PLF Long
Payload Type	5m PPL	5m PPL	5m SPL	8.4m CPL	8.4m PPL	8.4m PPL	10m PPL	8.4m PPL	10m PPL
Length	47.0 ft	62.7 ft	4.85 ft	32.8 ft	47.2 ft	62.7 ft	62.7 ft	90 ft	90 ft
	14.3 m	19.1 m	1.48 m	10.0 m	14.4 m	19.1 m	19.1 m	27.4 m	27.4 m
Diameter	16.7 ft	16.7 ft	17.7 ft	27.6 ft	27.6 ft	27.6 ft	33.0 ft	27.6 ft	33.0 ft
	5.1 m	5.1 m	5.4 m	8.4 m	8.4 m	8.4 m	10.0 m	8.4 m	10.0 m
Internal Diameter	15.1 ft	15.1 ft	16.7 ft	24.6 ft	24.6 ft	24.6 ft	29.9 ft	24.6 ft	29.9 ft
	4.6 m	4.6 m	5.1 m	7.5 m	7.5 m	7.5 m	9.1 m	7.5 m	9.1 m
Available Volume	5,358 ft³	8,118 ft³	516 ft³	10,100 ft³	11,260 ft³	21,930 ft³	32,470 ft³	34,910 ft³	46,610 ft³
	151.7 m³	229.9 m³	14.6 m³	286.0 m³	319 m³	621 m³	919 m³	988 m³	1,320 m³
Potential Availability *(No Earlier Than)*	COTS	COTS	2020	2024	2025	2025	2029	2029	2029

Block 2

COTS: Commercial Off-the-Shelf CPL: Co-manifested Payload OSA: Orion Stage Adapter PPL: Primary Payload SPL: Secondary Payload PLF: Payload Fairing



SLS BLOCK 1 CREW/CARGO INTEGRATED SPACECRAFT/PAYLOAD ELEMENT (ISPE)
SLS Block 1 Elements
(Crew Configuration)
Orion Spacecraft
ISPE
Booster
Booster
Stages (Core)
SLS Block 1 Payload
Secondary Payload (SPL)
Up to 16 places ≤12U
Orion Stage Adapter (OSA)
Interim Cryogenic Propulsion Stage (ICPS)
Launch Vehicle Stage Adapter (LVSA)
5m Payload Fairing (PLF)
Primary Payload (PPL)
Payload Adapter (PLA)
SLS Block 1 Elements
(Cargo Configuration)
Integrated Spacecraft/Payload Element (ISPE)
Booster
Booster
Stages (Core)
www.nasa.gov/sls
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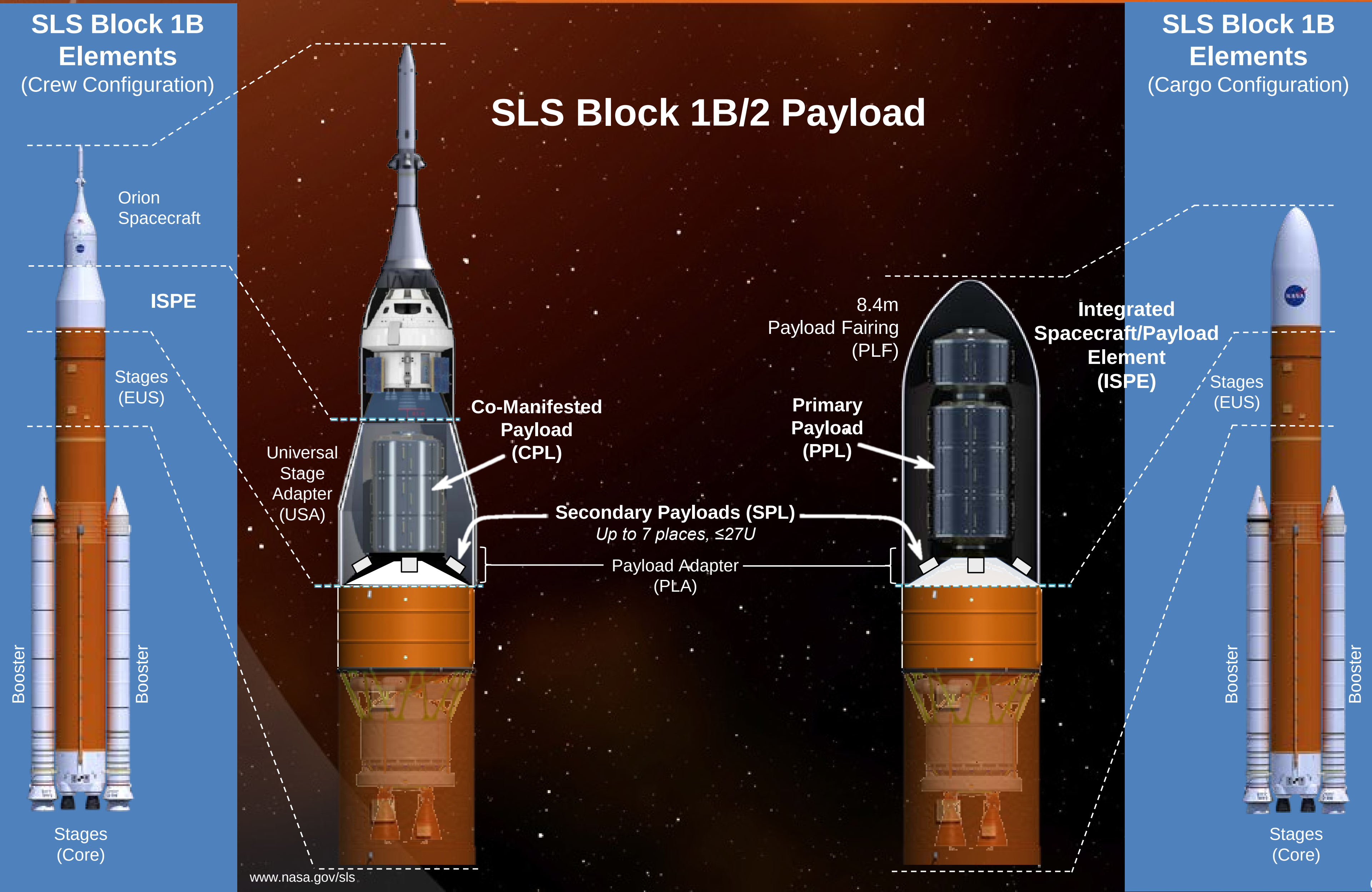
SLS BLOCK 1B CREW/CARGO INTEGRATED SPACECRAFT/PAYLOAD ELEMENT (ISPE)



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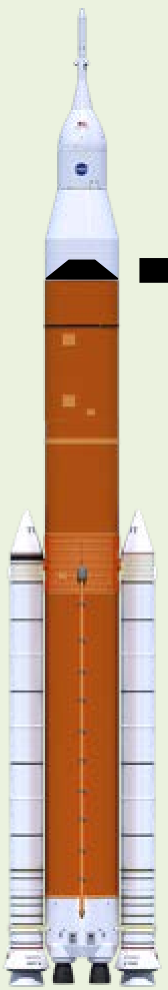
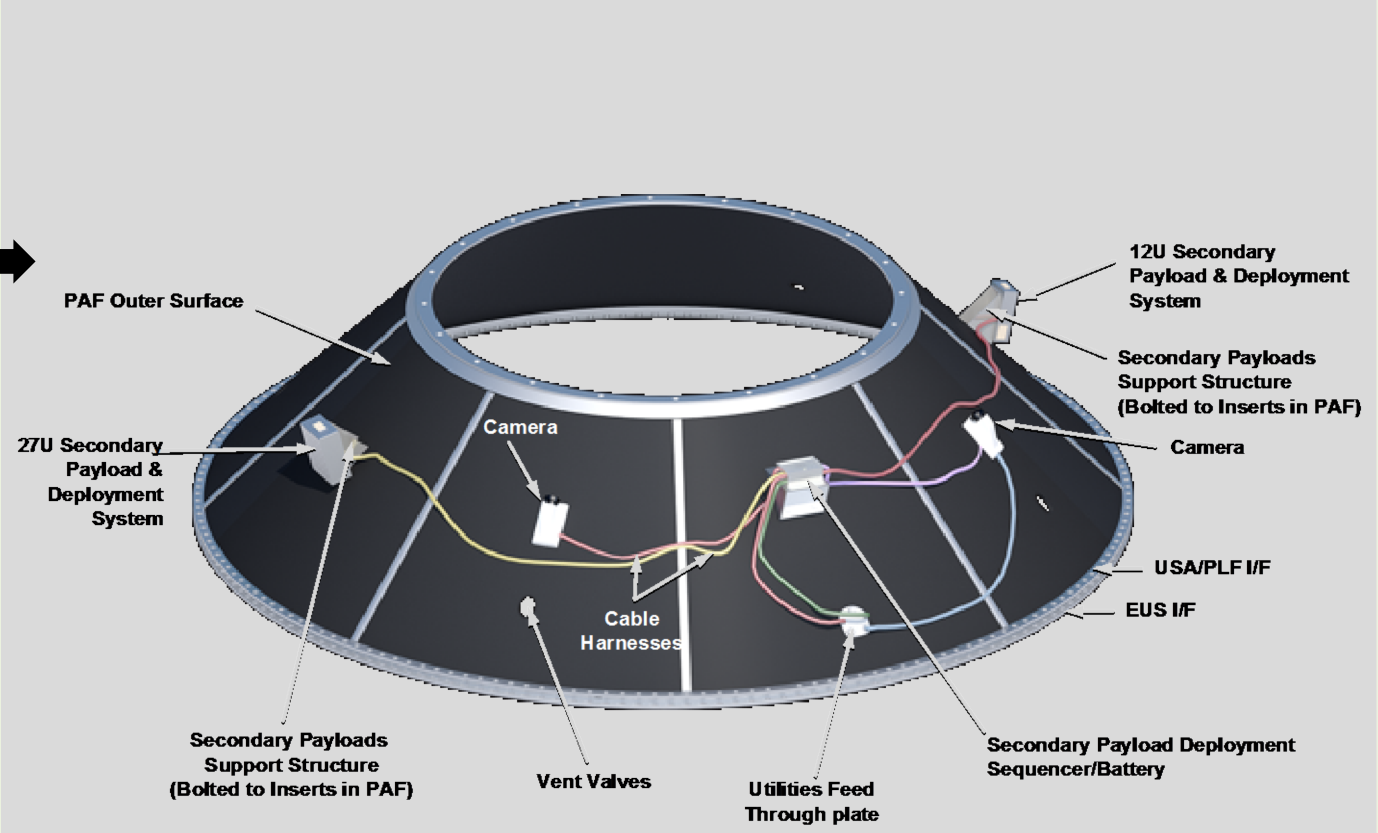
SLS 8.4m PLA CONCEPT



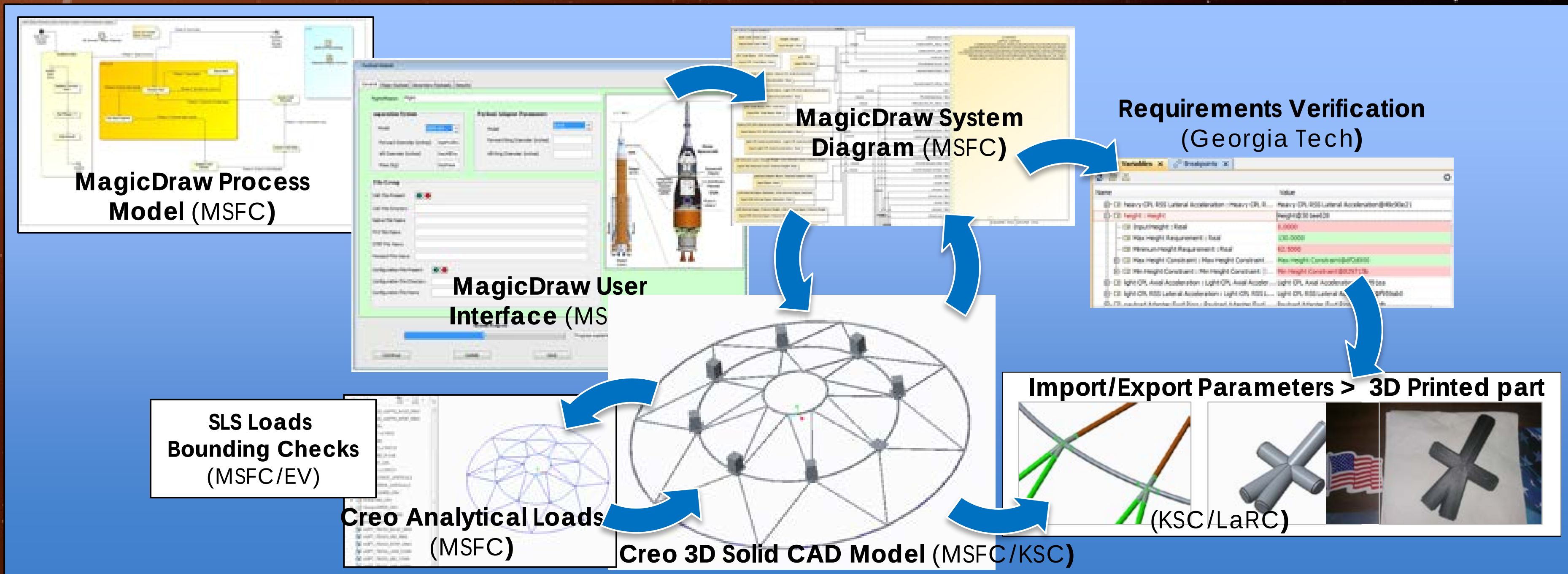


Payload Adapter (PLA)

PLA MBSE APPROACH

- Gather stakeholder requirements from existing documents and COTS specifications
- Develop User Interface (UI) to capture PLA accommodation attributes, such as payload destination, mass, width, height, potential loads, etc.
- Requirements and user data represented as a CAD model
  - Needed updates to PLA design will be by parameter modifications
  - Loads/stress analyses made within CAD modeling function
  - Results are exported along with any parameter updates into a SysML MagicDraw model
- Model verification will indicate that requirements were successfully verified and which were not

MBSE PATHFINDER: SLS PLA DESIGN DEFINITION INTEGRATING RQMTS/CAD/FEM/VERIFICATION TO REDUCE CHANGES/TIME TO PRODUCTION



Technical Challenge

SLS engineering resources insufficient to evaluate 10's-100's of optimized PL adapter options for SLS users over life of program

MBSE Challenge

Develop User Interface to feed MagicDraw parameters into CAD/analytical model and verify requirements were met by PL adapter concept

Pathfinder Findings

- **Benefits**:
  - Outward facing GUI for capture of SLS payloads
  - Automated concept design of PL integrated to SLS
  - Demonstrated MBSE to MBE for design and mfg.
  - Minimizes error from manual steps in integration
  - Matures design to higher fidelity quickly
- **Next Step**: Develop front-end SLS user interface within existing SLS Mission Planners Guide

CONCLUSIONS

- **NASA is moving toward more digitally integrated solutions that span life-cycle from concept to manufacturing**

- **Unique scale of SLS and associated payload accommodation options benefits from a MBSE PLA approach**
  - Partial "automation" of analysis cycle provides analysts with a 75% fidelity answer at the beginning of their detailed analysis
  - Allows potential users to "self analyze" accommodation feasibility on SLS sooner
  - Provides SLS with enough fidelity to determine feasibility of optimizing payload complement sooner
    - Insight into whether existing PLA design is sufficient or use of new design is worth performance enhancement investment
    - Ability to accommodate single payload or fly multiples on one mission
    - Opportunity to trade performance to destination for different payloads

FUTURE WORK

- **Compare MBSE finding to the full range of NASA missions ranging from Super Heavy to Sounding Rocket launch vehicles as well as Habitat to Nanosat spacecraft**

- **Understand where MBSE provides the biggest return soonest**
  - Determine where models and data can flow most easily and efficiently
  - Application should include internally to a launch vehicle or spacecraft as well as externally across a range of launch vehicle and spacecraft delivery providers

- **Ultimate goal is more detailed design/analysis improvements earlier resulting in less re-work across not only physical interfaces, but the entire federated infrastructure**